Activity 3 Metamorphic Rocks and Your Community

Goals

In this activity you will:

- Identify and classify several metamorphic rocks using a rock chart.
- Describe two agents of metamorphism.
- Use a geologic map to search for evidence of past metamorphism in a community.
- Understand that properties of materials can change over time.

Think about It

Metamorphism is the "magic" that transforms one rock into a new form.

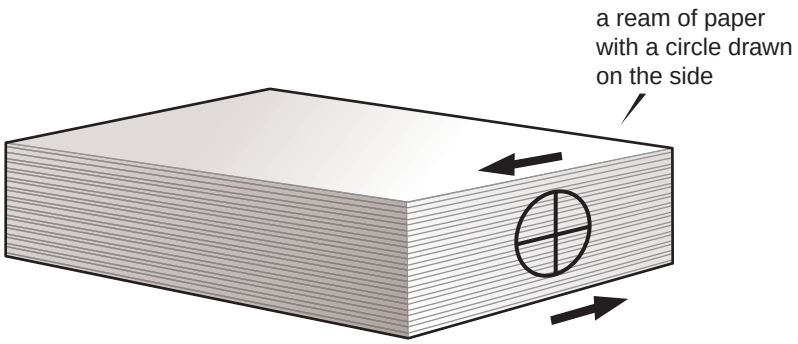
- What factors are responsible for changing a rock from one form to another?
- Where does metamorphism occur?

What do you think? Record your ideas about these questions in your *EarthComm* notebook. Provide a sketch. Be prepared to discuss your responses with your small group and the class.

Investigate

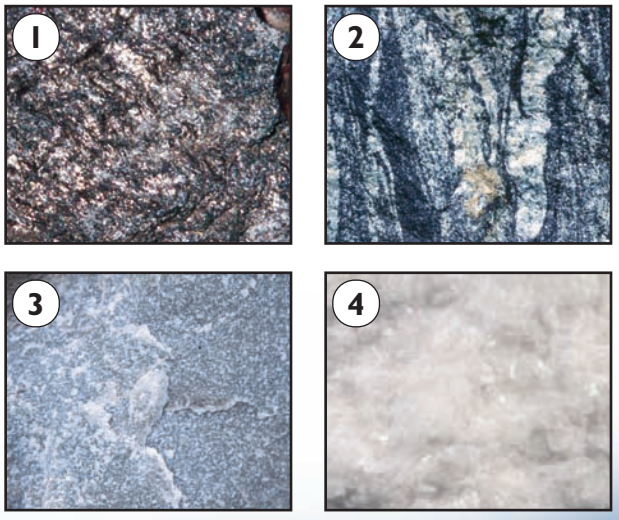
Part A: Modeling Deformation during Metamorphism

1. Obtain a ream (500 sheets) of paper, or an old, very thick (at least 3 cm) telephone book or catalog.
2. On the side of the stack of sheets, draw a large circle. Then draw a straight line through the center of the circle and parallel to the sheets, and another straight line perpendicular to the sheets. See the diagram below.
3. Change the shape of the stack of sheets or pages by sliding them parallel to one another so that the stack "leans sideways." Change in the shape of an object is called deformation. The kind of deformation you are producing here is called shear. If you use a ream of paper rather than a book or catalog, you will be able to make the stack lean farther (in other words, you will be able to make it deform more).
   a) How does the shape of the circle change when you deform the stack?
   b) How does the line parallel to the sheets change when you deform the stack?
   c) How does the line perpendicular to the sheets change when you deform the stack? Record your observations in your notebook along with a sketch of the stack before and after deformation.
4. What do you think would happen to a rock if it is sheared in the same way as the ream of paper or the book?
   a) Record your conclusions in your notebook. Compare your conclusions with those of the other groups, and discuss any differences in your conclusions.



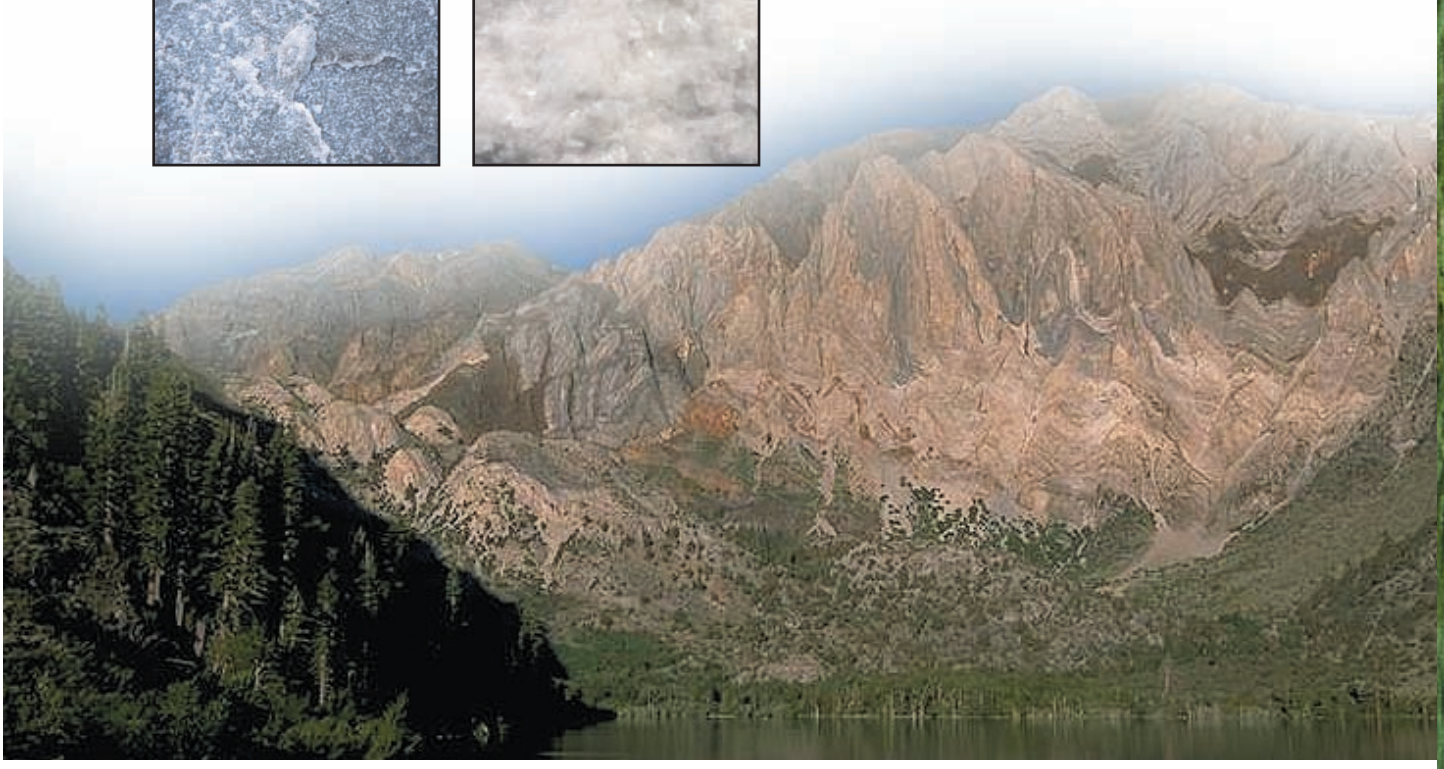
Part B: Classifying Metamorphic Rocks

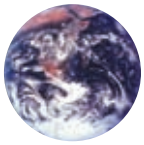
1. Examine the photograph of the collection of metamorphic rocks (or obtain rock samples) and the chart on the following page.
   a) What properties do geologists use to classify metamorphic rocks?
   b) Use the metamorphic rock chart to identify your rock samples (or the pictured rocks).



Part C: Evidence of Metamorphic Rocks in Your Community

1. Examine the geologic map of your community or region.
   a) Are any metamorphic rocks described in the legend? If so, make a list of the rock type, locations, and ages (in millions of years). Record your observations in a data table. If there are numerous metamorphic rocks in your community, limit your data table to several different examples. Be sure to include any evidence found in the area that you have selected for your Chapter Challenge.
   b) What are the most common metamorphic rocks in your area?





Classification of Metamorphic Rocks			
Texture	**Rock Name**	**Description**	**Rock before Metamorphism**
Strongly foliated: rocks in which platy minerals are arranged to be approximately parallel, causing the rock to split easily along parallel planes.	Slate	Very fine-grained, usually dark, splits easily along parallel planes.	Mudstone, claystone, shale.
	Phyllite	Fine-grained, usually dark, splits easily along parallel planes: often crinkled or folded. Not as fine-grained as slate.	Mudstone, claystone, shale.
	Schist	Medium-grained to coarse-grained, with parallel alignment of platy mineral grains like micas.	Mudstone, claystone, shale, some volcanic rocks.
Weakly foliated or nonfoliated: rocks without abundant platy mineral; the rocks do not split easily along parallel planes.	Gneiss	Medium-grained to coarse-grained rock, often with alternating layers of light and dark minerals.	Granite, rhyolite, some sandstones, some volcanic rocks.
	Marble	Usually light-colored, composed of calcite crystals.	Limestone
	Quartzite	Usually light-colored, composed of quartz crystals.	Quartz sandstone
	Greenstone	Dark green, fine-grained rock made of various minerals rich in iron and magnesium.	Basalt
	Amphibolite	Dark-colored, medium-grained to coarse-grained rock with abundant amphibole minerals.	Basalt

Reflecting on the Activity and the Challenge

In this investigation, you saw how materials can be deformed by shear. You also examined samples of metamorphic rocks and searched for evidence of metamorphic rocks in your community. Understanding how rocks are changed will help you interpret the geological history of your area and complete your Chapter Challenge.

Digging Deeper

Formation of Metamorphic Rocks

Sedimentary rocks and igneous rocks can be metamorphosed (turned into a **metamorphic rock**) if they are subjected to high temperatures and/or pressures. The changes occur while the rock is still solid, before the temperature becomes so high that part of the rock melts. If the temperature becomes too high, part of the rock melts to form a magma, which later cools to form an igneous rock. The basic idea behind metamorphism is that a crystal of a mineral can grow only in a certain range of temperature and pressure. If a mineral crystal in a rock is subjected to the high temperatures and pressures of metamorphism, it is likely to be outside of its range of temperature and pressure, and it is changed into crystals of one or more different minerals. This is why the minerals in a metamorphic rock are usually very different from the minerals in the original rock. A few common minerals, however, like quartz and calcite, are "just as happy" under metamorphic conditions as they are near the Earth's surface. When a limestone is metamorphosed, the calcite continues to exist, but the crystals grow to be much larger, and all evidence of the original features of the limestone, like fossils, are destroyed.

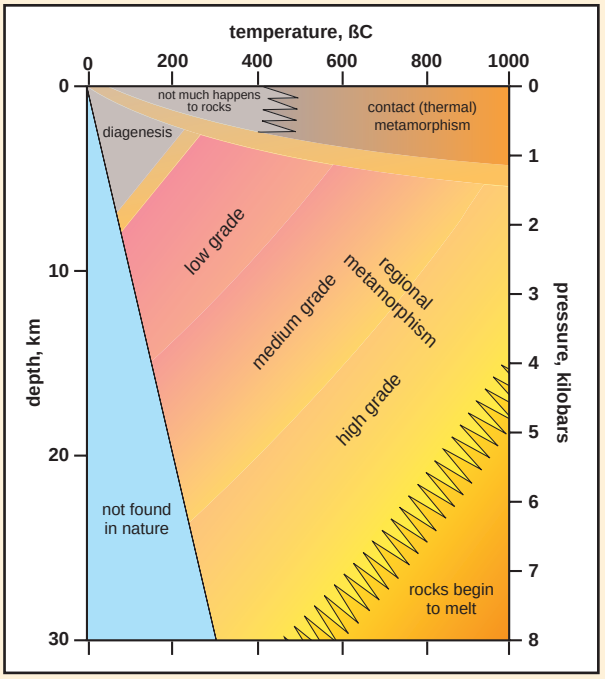
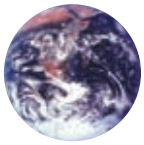


Figure 1 Diagram to explain regional metamorphism.

Geo Words

metamorphic rock: rock that has been changed (metamorphosed) into a different rock type, without actually melting, by an increase in temperature and/or pressure, and/or the action of chemical fluids.



Geo Words

fault: a fracture or fracture zone in rock, along which rock masses have moved relative to one another parallel to the fracture.

regional metamorphism: a general term for metamorphism affecting an extensive region.

By using special pressurized furnaces in the laboratory, geoscientists have learned a lot about the conditions of temperature and pressure that are characteristic of metamorphic minerals. The kinds of metamorphic minerals in a rock can then tell a story of what the temperatures and pressures in the Earth were where the rock was metamorphosed.

The temperature of a rock can be increased in two ways. Rocks can become buried deeper and deeper in the Earth. This can happen either by deposition of a very thick layer of sediment on top of the rock, or by Earth movements that shove very thick masses of rock on top of the rock by movement along **faults**. As the rock is buried, its temperature gradually increases. That is because the temperature in the Earth increases with depth. Enormous volumes of rock can be metamorphosed in this way by deep burial. This is the most important kind of metamorphism. It is called **regional metamorphism**, because large regions of the Earth's crust can be affected in this way. The temperature of a rock can also be increased if a body of magma is put into place near the rock. As the magma cools, the surrounding rock is heated, and this can metamorphose the rock, as shown in *Figure 2*. If the igneous intrusion is small, only a thin layer of the surrounding rock is metamorphosed, but very large intrusions can metamorphose the surrounding rock for thousands of meters away from the intrusion. The intensity of metamorphism decreases gradually away from the contact with the intrusion.

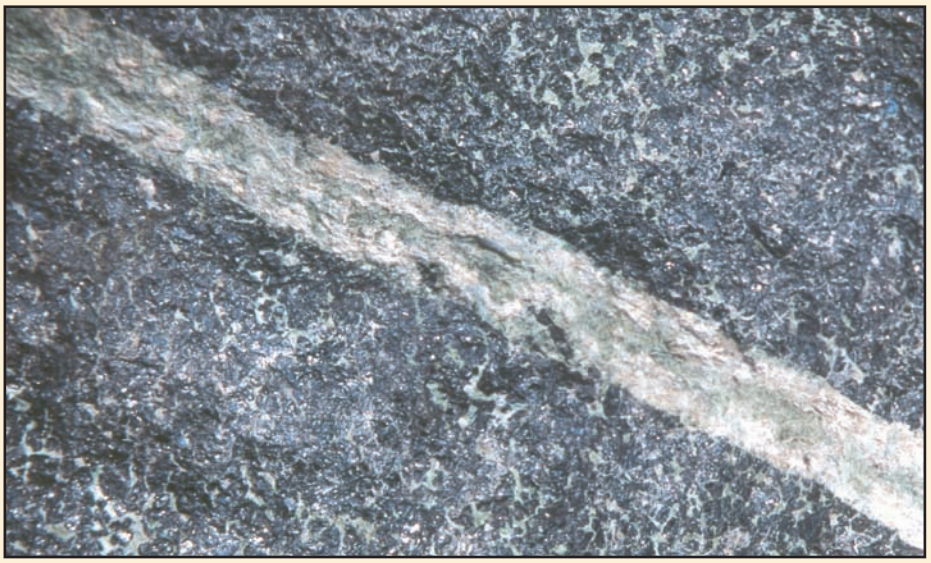


Figure 2 When an igneous rock intrudes another rock, the intense heat of the intrusion can result in metamorphism of the surrounding rock. This is known as contact metamorphism.

Deformation in Metamorphism

Extreme deformation (change in the shape of a material) is common during regional metamorphism. In Part A of the investigation you modeled the deformation of a rock by shearing. The same thing happens, although usually even more so, when rock is sheared by forces within the Earth. This is especially common where one lithospheric plate slides down beneath another. You saw in the investigation that when a material is sheared, lines or planes within it become more nearly parallel. This is called **transposition**. In many metamorphic rocks, all kinds of features and structures are "smeared out" by transposition to become nearly parallel planes. The layering you see in a metamorphic rock may not have anything to do with layering in the original rock! Forces within the Earth can also stretch or compress the rock. In some metamorphosed conglomerates, the pebbles are stretched into the shape of cigars.

Geo Words

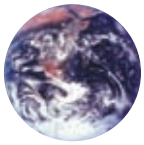
transposition: the process by which lines or planes within a material become more nearly parallel when they are sheared.

foliation: the tendency for a metamorphic rock to split along parallel planes.

Foliation in Metamorphic Rocks

Figure 3 This gneiss is an example of a strongly foliated metamorphic rock.

Sedimentary rocks like claystone, mudstone, and shale contain a high percentage of very fine flakes of mica minerals. These rocks become metamorphosed first to slate, then to phyllite, and then to schist, as the intensity of metamorphism increases. As you saw in the classification table earlier in this activity, all of these rocks tend to split easily along parallel planes. This is because the mica minerals in the rock have grown to be



parallel to one another, causing weakness in the direction parallel to the planes of the mineral grains. This parallel growth develops for a combination of two reasons. First, the mica minerals grow with their planes perpendicular to the direction of greatest force on the rock. Second, when the rock is sheared the mica grains tend to become parallel, as you learned earlier. The tendency for a metamorphic rock to split along parallel planes is called **foliation.** Foliation, as shown in the photograph in *Figure 3* is a very prominent feature of many metamorphic rocks.

The Protoliths of Metamorphic Rocks

The rock from which a metamorphic rock was formed is called the **protolith** of the metamorphic rock. Both sedimentary and igneous rocks are commonly the protoliths of metamorphic rocks. Geoscientists who study metamorphic rocks are always interested in trying to figure out what the protolith was. Sometimes that is easy; for example, a quartzite probably started out as a quartz sandstone, and a marble probably started out as a limestone. Sometimes, however, it is very difficult to guess the protolith.

Figure 4a Quartz sandstone.

Figure 4b Quartzite.

Geo Words

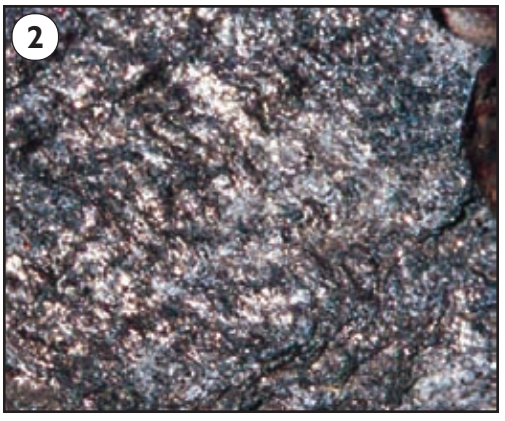
protolith: the rock from which a metamorphic rock was formed.

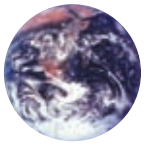
Check Your Understanding

1. Describe in your own words two sources of heat that lead to metamorphism.
2. Why do temperature and pressure increase with depth in the Earth?
3. Why is the mineral composition of a metamorphic rock usually different from the mineral composition of the protolith (the original rock)?

Understanding and Applying What You Have Learned

1. Why is foliation more likely to occur during mountain building than through the contact of rock with magma?
2. Why are some metamorphic rocks foliated but others lack foliation?
3. Calculate the mass (kg) of a column of rock one meter square (m^2) and 100 m deep. Assume that the density of the rock is 2700 kg/m^3. Repeat this for a depth of 500 m, 1 km, 2 km, 4 km, 8 km, and 16 km. Graph your results. Use your results to describe the relationship between pressure and depth in the Earth. (Remember that 1 km = 1000 m.)
4. Look at the photographs of the metamorphic rocks, or the samples of metamorphic rocks provided by your teacher.
   a) Are the rocks foliated or non-foliated?
   b) What are the names of these metamorphic rocks?
   c) How did these rocks form?
5. Examine the geologic map of your state and your list of metamorphic rocks found in the region covered by the map. Look at the ages of the metamorphic rocks in your area. Did you find evidence of more than one period of metamorphism? Discuss reasons why you might see more than one time period of metamorphism.
6. In your own words, describe how metamorphic rocks demonstrate the principle that the properties of materials can change over time. Discuss crystal size, foliation, and hardness.
7. Suppose you found gneiss and/or schist in a region that currently has no mountains. How would you use this evidence to describe to a friend that there used to be mountains in that region?





Preparing for the Chapter Challenge

You have learned how metamorphic rocks are formed. You have also learned that looking at the features in a rock can provide clues about the history of the rock. The history of the rock will help you understand how the land's surface has changed. You have also gathered information about metamorphic rocks from the geologic map. Using this information, you can add to your understanding of the geological history of your community. Write a one or two paragraph description about the events and evidence for metamorphism in your state and in your local area.

Inquiring Further

1. **Metamorphism in the United States**

   Research the history of the formation of metamorphic rocks in the Appalachian Mountains.

2. **Metamorphism and mineral resources**

   A third major type of metamorphism is that caused by the movement of heated solutions of mineral-rich groundwater. The groundwater is heated by bodies of hot magma. Investigate how hydrothermal alteration leads to the formation of deposits of valuable minerals like gold, silver, and copper.